PAYLOAD FLIGHT HAZARD REPORT		a. NO: AMS-02-F10
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)		c. PHASE: II
d. SUBSYSTEM: Materials, Thermal Control System	e. HAZARD GROUP: Fire/Flammability	f. DATE: March 31, 2006
g. HAZARD TITLE: Flammable Materials in the Payload Bay		i. HAZARD CATEGORY: CATASTROPHIC X CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS: NSTS 1700.7B 209.2		
j. DESCRIPTION OF HAZARD: Use of flammable materials, solid or gaseous, in the Orbiter Payload Bay can present an uncontrolled fire hazard to the Orbiter and other payloads. Note: Shuttle Cabin flammability issues are addressed in STD-AMS-02-F02.		
k. CAUSES *(list)* 1. Use of flammable materials in the construction of the AMS-02 2. Use of flammable fluids/gases in the AMS-02 Thermal Control System		

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

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l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: Use of flammable materials in the construction of the AMS-02	
1.1 CONTROL: Materials used in the construction of the AMS-02 hardware to be locate in the shuttle payload bay will be "A" rated for flammability as rated in the MAPTIS database or will be included in a flammability assessment per NSTS 22648. 1.1.1 SVM: Review of design. 1.1.2 SVM: Inspection of as built hardware. 1.1.3 SVM: Material Certification by JSC ES4. 1.1.1 STATUS: Open 1.1.2 STATUS: Open 1.1.3 STATUS: Open	
2. CAUSE: Use of flammable fluids/gases in the AMS-02 Thermal Control System	
2.1 CONTROL: The Tracker radiators/thermal control system radiators incorporate heat pipes that utilize ammonia as a working fluid. There are 7 individual heat pipes in each of the Tracker radiators each containing 22.3 to 26.3 grams of ammonia. Ram and Wake Tracker radiators heat pipes are identical with regards to ammonia and heat pipe use. All of these heat pipes are qualified under NSTS 1700.7B 208.4C Pressurized Lines, Fittings and Components. Reference AMS-02-F05. 2.1.1 SVM: Review of design to establish flammable material quantity. 2.1.2 SVM: Flammability assessment on the use of ammonia in the payload bay. 2.1.1 STATUS: Open 2.1.2 STATUS: Open	
2.2 CONTROL: The Electronics Crate thermal control system radiators (Ram and Wake) incorporate heat pipes that utilize ammonia as a working fluid. There are 24 individual heat pipes in the Wake Radiator with a maximum ammonia quantity of 30.2 grams and 16 individual heat pipes with the maximum ammonia quantity of 40.7 grams in the Ram Radiator. All of these heat pipes are qualified under NSTS 1700.7B 208.4C Pressurized Lines, Fittings and Components. Reference AMS-	

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02-F05. 2.2.1 SVM: Review of design to establish flammable material quantity. 2.2.2 SVM: Flammability assessment on the use of ammonia in the payload bay. 2.2.1 STATUS: Open 2.2.2 STATUS: Open	
2.3 CONTROL: The Cryocooler Loop Heat Pipe Radiators incorporate heat pipes that utilize propylene as a working fluid to transport heat to the Zenith Radiators. There are four sets of dual loop heat pipes in the Zenith radiators each loop containing 42 grams of propylene. All of the heat pipes are qualified under NSTS 1700.7B 208.4C Pressurized Lines, Fittings and Components. Reference AMS-02-F05. 2.3.1 SVM: Review of design to establish flammable material quantity. 2.3.2 SVM: Flammability assessment on the use of propylene in the payload bay. 2.3.1 STATUS: Open 2.3.2 STATUS: Open	
2.4 CONTROL: The CAB Loop Heat Pipe utilizes 55 grams of ammonia as a working fluid. The CAB Loop Heat Pipe is a closed loop that does not incorporate vents or valves that may released the ammonia. The CAB Loop Heat Pipe is qualified as a pressure system under NSTS 1700.7B 208.4 Pressure Systems. Reference AMS-02-F05. 2.4.1 SVM: Review of design to establish flammable material quantity. 2.4.2 SVM: Flammability assessment of the use of ammonia in the payload bay. 2.4.1 STATUS: Open 2.4.2 STATUS: Open	
2.5 CONTROL: The USS heat pipes utilize 7 grams of ammonia as a working fluid. The USS heat pipes are a closed system that does not incorporate any nominal venting means. The USS heat pipes are qualified under NSTS 1700.7B, 208.4C Pressurize Lines, Fittings and Components. Reference AMS-02-F05. 2.5.1 SVM: Review of design to establish flammable material quantity. 2.5.2 SVM: Flammability assessment on the use of ammonia in the payload bay. 2.5.1 STATUS: Open	

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2.5.2 STATUS: Open

2.6 CONTROL: The TTCS Accumulator Heat Pipes utilize 3 grams of ammonia as a working fluid. The TTCS Accumulator Heat Pipe is a closed system that does not incorporate any nominal venting means. The TTCS Accumulator Heat Pipe is qualified under NSTS 1700.7B, 208.4C Pressurized Lines Fittings and Components. Reference AMS-02-F05.

2.6.1 SVM: Review of design to establish flammable material quantity.

2.6.2 SVM: Flammability assessment on the use of ammonia in the payload bay.

2.6.1 STATUS: Open

2.6.2 STATUS: Open

NOTES:

ACRONYMS	
ACOP – AMS Crew Operations Post	MAPTIS - Materials and Processes Technical Information System
AMS-02 – Alpha Magnetic Spectrometer -02	SVM – Safety Verification Method
CAB – Cryomagnet Avionics Box	TCS – Thermal Control System
DFMR – Design for Minimum Risk	USS – Unique Support Structure

Summary of Flammable Gas/Fluid use in AMS-02 Heat Pipes

System	Number of Heat Pipes	Quantity per Heat Pipe	Construction
CAB Loop Heat Pipe	1	53 grams of ammonia	Stainless Steel (AISI 321) tubes for vapor and liquid lines, Stainless Steel (AISI 321 reservoir and evaporator and AL 6063 condenser.
Cryocooler Thermal Control System/Zenith Radiators	Four redundant systems, each system with dual loops	42 grams pure propylene per loop	Four: Aluminum (6063) of 3mm OD, 2mm ID soldered to the underside of radiator sandwich material (1.6 mm aluminum sheet/10mm ROHACELL core/0.3mm aluminum lower sheet) connected through stainless steel tubes to sterling engines (Cryocoolers). Stainless steel tube with internal wick evaporators are used.
Wake Crate Radiator	Twenty-four heat pipes of various lengths and bends fitted to radiator	Total: 331.3 grams Largest single ammonia quantity: 30.2 grams	Aluminum alloy face sheets of each 0.5 mm thickness, ROHACELL 51 core of 25 mm height (density 51 kg/m3) with embedded heat pipes, aluminum tubes with internal capillary structure Identical internal heat pipe profile
Ram Crate Radiator	Sixteen heat pipes of various lengths and bends fitted to radiator	Total: 292.4 grams Largest single ammonia quantity:40.7 grams	Aluminum alloy face sheets of each 0.5 mm thickness, ROHACELL 51 core of 25 mm height (density 51 kg/m3) with embedded heat pipes, aluminum tubes with internal capillary structure Identical internal heat pipe profile
Tracker Radiator Wake	Seven heat pipes varying in length from 2125 mm to 2505 mm	Total quantity: 170.05 grams Individual heat pipes range from 22.3 to 26.3 grams ammonia	Aluminum alloy face sheets of 0.8 mm thickness on radiating side and 0,2 mm on opposite side. ROHACELL 51 core of 15 mm height (density 51 kg/m3) with 7 embedded heat pipes. Extruded aluminum with internal capillary structure heat pipes
Tracker Radiator Ram	Seven heat pipes varying in length from 2125 mm to 2505 mm	Total quantity: 170.05 grams Individual heat pipes range from 22.3 to 26.3 grams ammonia	Aluminum alloy face sheets of 0.8 mm thickness on radiating side and 0,2 mm on opposite side. ROHACELL 51 core of 15 mm height (density 51 kg/m3) with 7 embedded heat pipes. Extruded aluminum with internal capillary structure heat pipes
USS Heat Pipes	Three heat pipes	7 grams of Ammonia per pipe.	Axial groove heat pipes constructed of Al 6063
TTCS Accumulator Heat Pipe	Two heat pipes, one per accumulator	3 grams of Ammonia	Stainless 316L tube with internal wicking materials. 232 mm long, OD 10.06 mm, ID 7.6 mm
CAB Heat Pipe	Two Heat Pipes	5 grams of Ammonia 7 grams of Ammonia	Axial groove heat pipes constructed of Al 6063

Flammable Fuels in the Payload Bay

- Memo ES5-91-289 addressed the flammability of gases in the Payload Bay.
- The following equation is used to calculate the weight of gas required to achieve a flammable mixture:

$$W_f = 27.05 * LFL * V_f * MW$$

Where,

W_f = weight of fuel to produce a flammable mixture
LFL = Lower Flammability Limit
V_f = Free Volume Fraction
MW = Molecular Weight (g/mol)

AMS-02 Coolant Summary

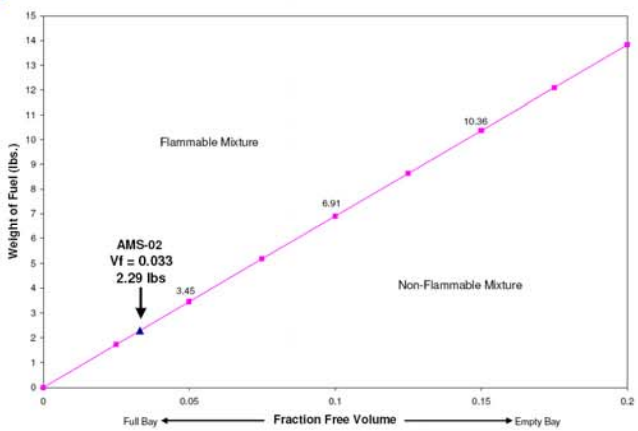
- The various AMS-02 thermal control systems use both Ammonia and Propylene as coolant materials.
- Quantities:

Fluid/Gas	Largest Single Qty	Total Qty
Ammonia	53 grams	1037.7 grams
Propylene	42 grams	168 grams

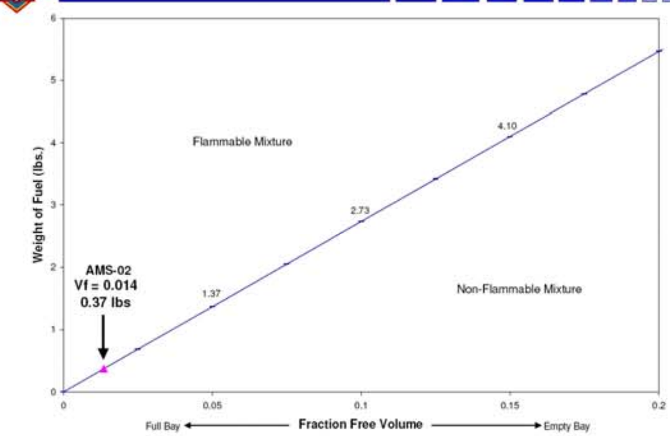
TOTAL Ammonia = 1037.7 grams = 2.3 lbs.
TOTAL Propylene = 168 grams = 0.4 lbs.

*Note: "Largest Single Qty" implies the largest amount used in any individual DFMR system.

Ammonia in the Payload Bay



Propylene in the Payload Bay



Flammable Gas Conclusion

- Summary
  - AMS-02 uses 2.3 lbs of Ammonia and 0.4 lbs of Propylene
  - The largest quantity in any single DFMR system is 0.12 lbs of Ammonia and 0.09 lbs of Propylene.
  - The "critical" Free Volume Fractions are as follows:
    - 2.3 lbs of Ammonia - $V_f = 3.3\%$
    - 0.4 lbs of Propylene - $V_f = 1.4\%$
  - Preliminary Payload Bay configurations predict a Free Volume Fraction of greater than 50%
- Conclusion
  - AMS-02 does not present a flammable gas hazard in the Payload Bay. The total quantities of coolant available do not present a hazard if released until the Payload Bay is over 95% full.

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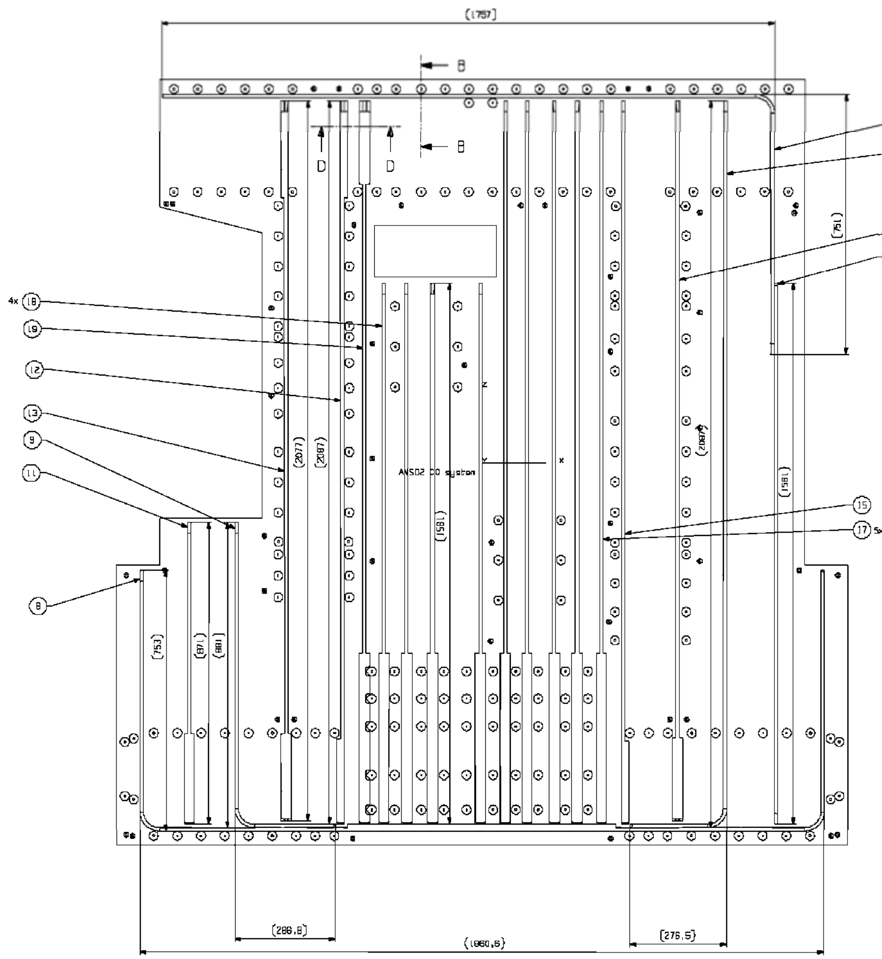
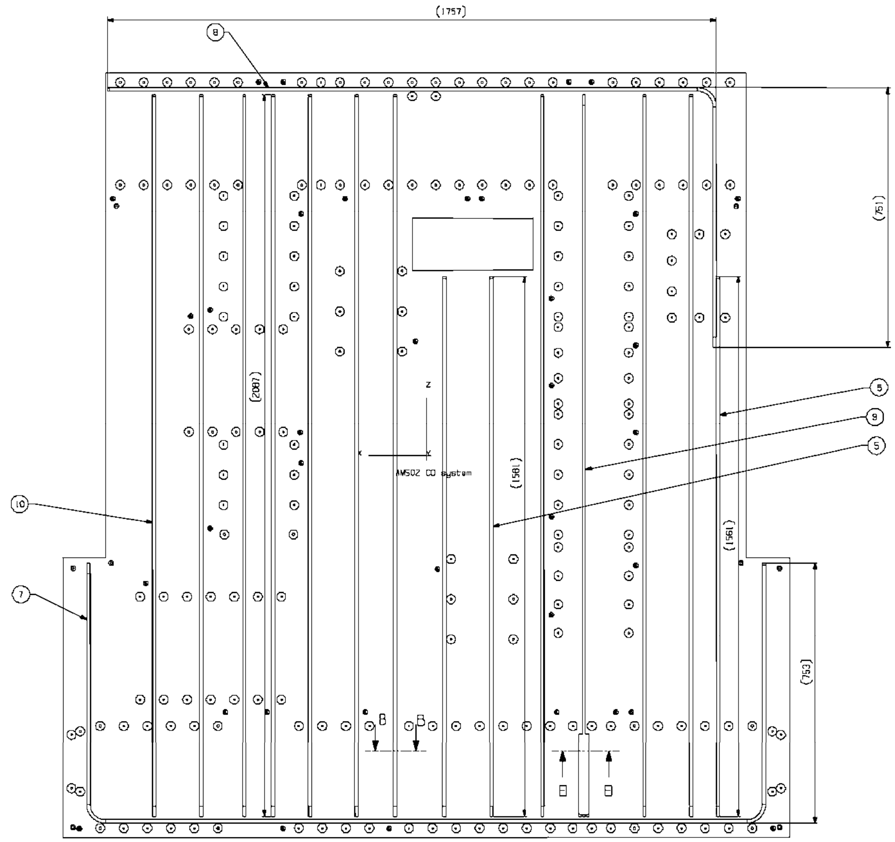
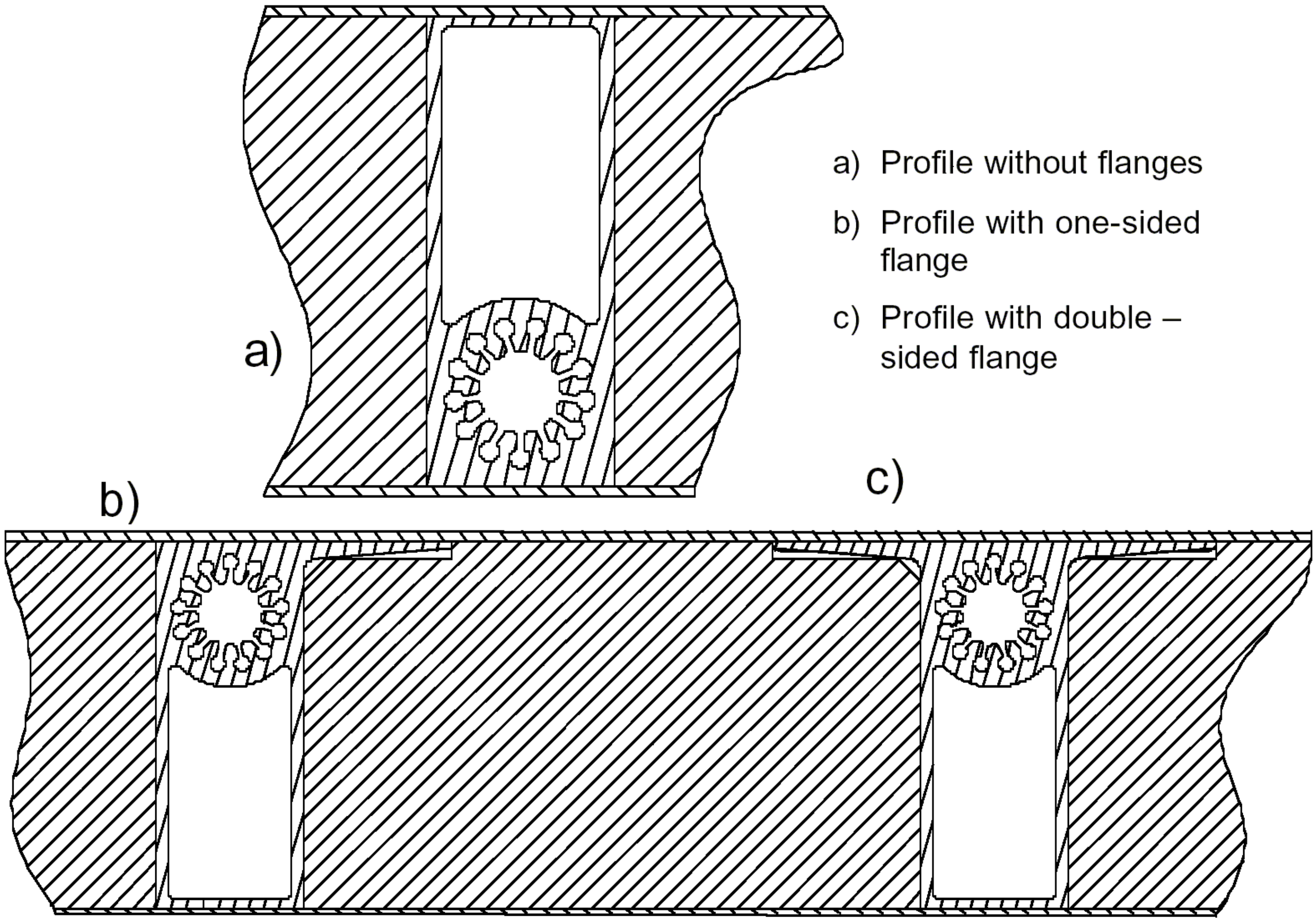
Worst case analysis of total release of flammable gasses indicates that the quantities of flammable gases used in the design of the AMS-02 are significantly below any flammability threshold.



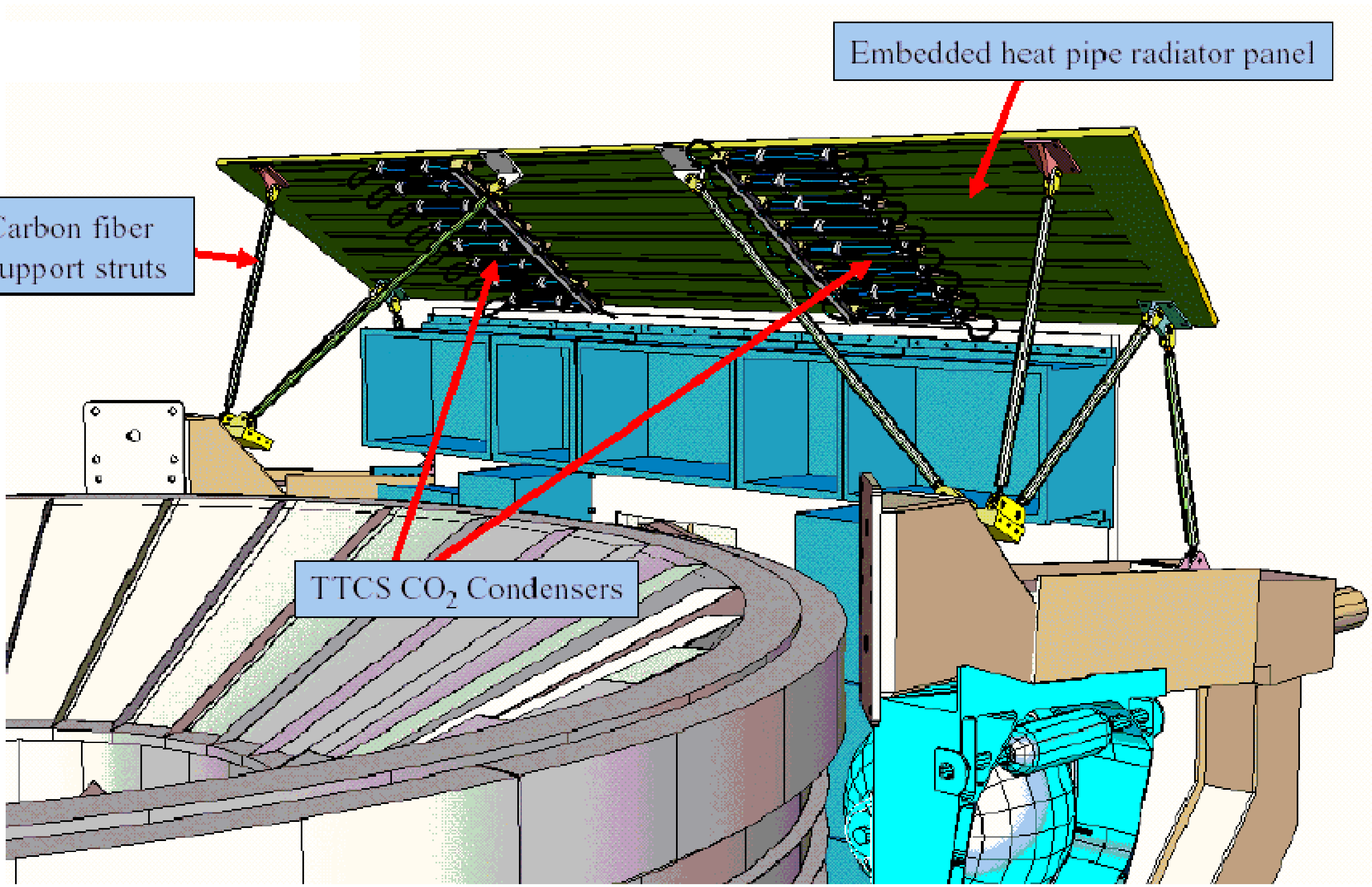
TCS – Wake Side Radiator for Avionics Crates



TCS – Ram Side Radiator for Avionics Crates

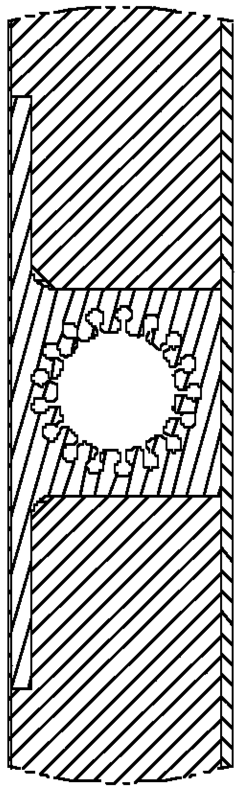


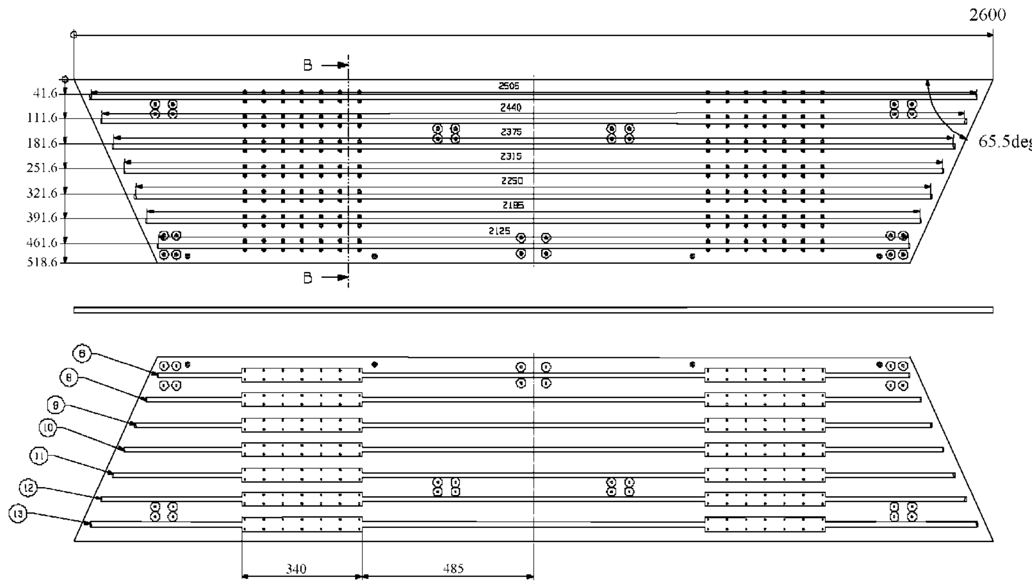
TCS Heat Pipe Profile – Axial Grooved



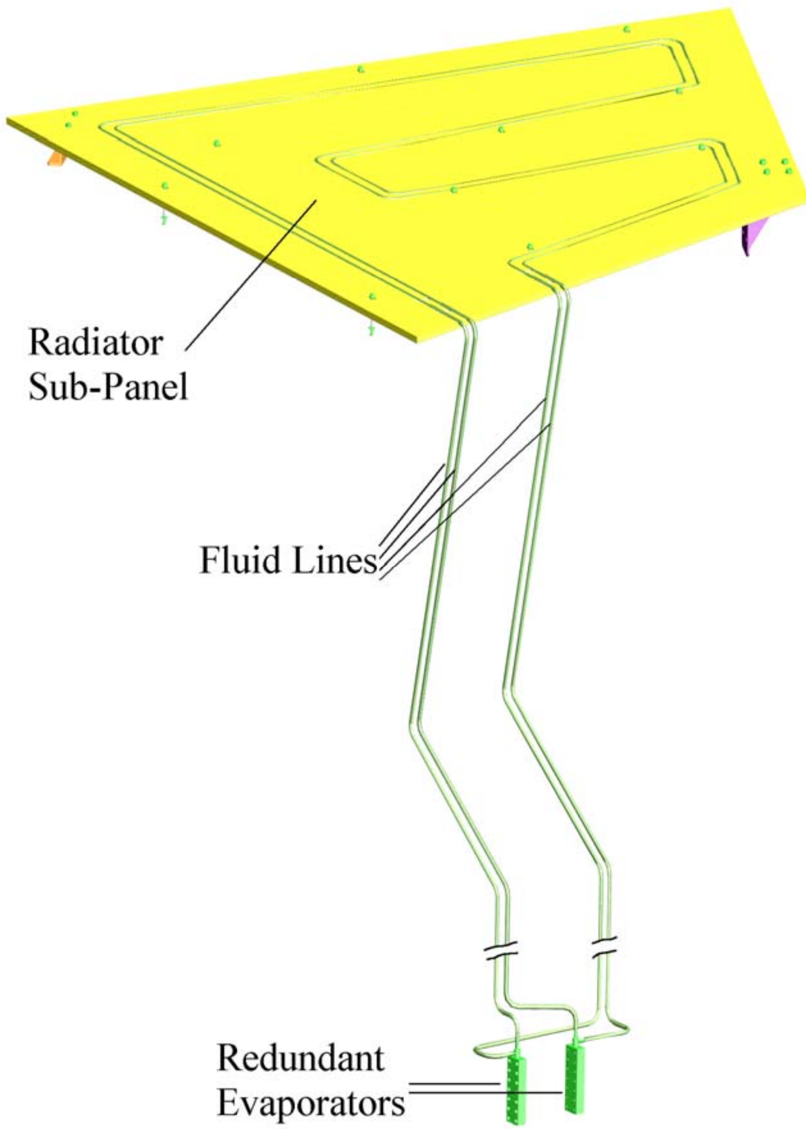
Tracker TCS Radiator

Tracker
Heat
Pipe

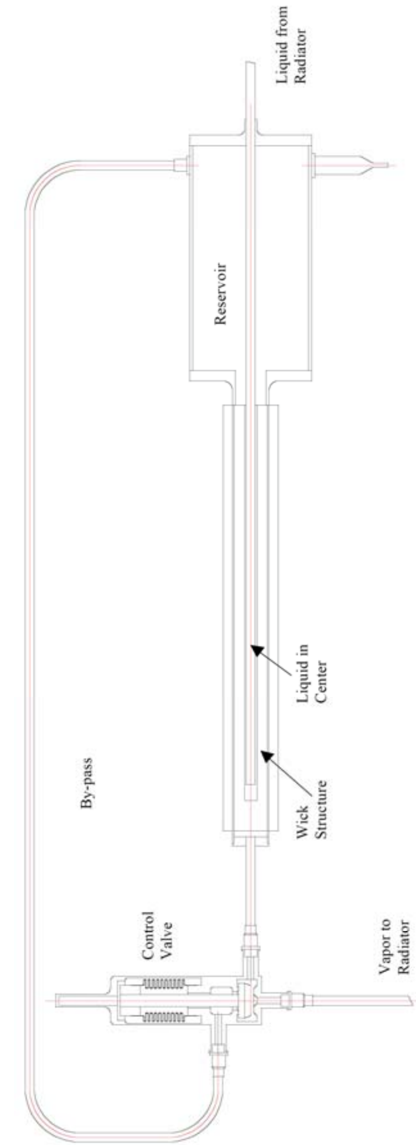




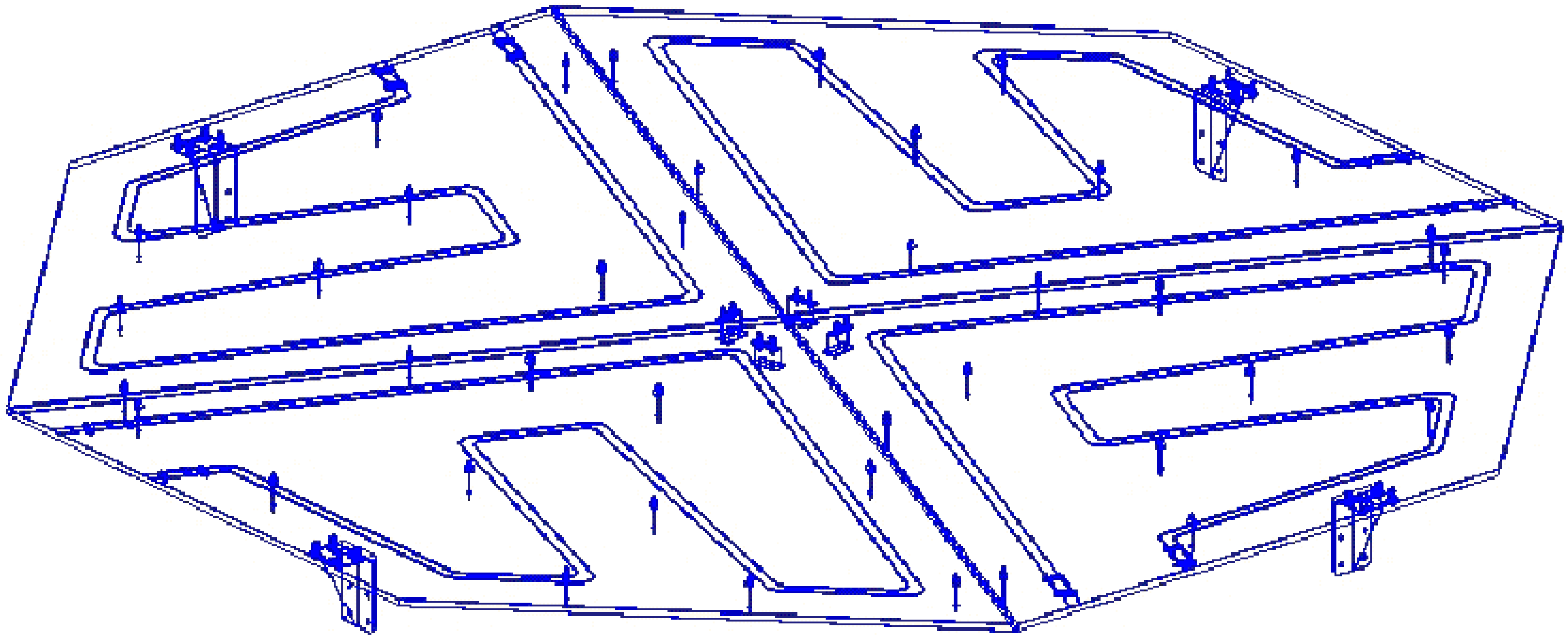
Tracker TCS Layout



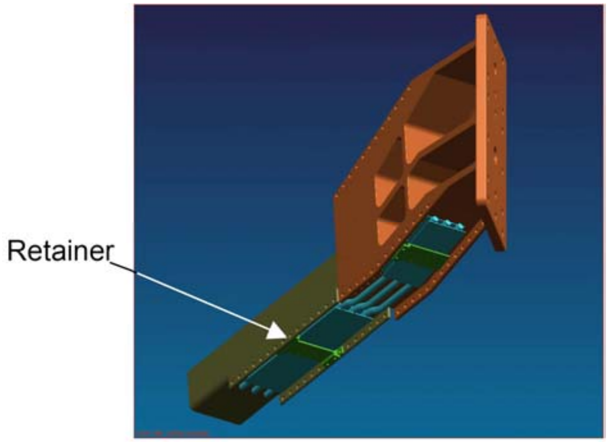
Cryocooler Zenith Radiator Sub Panel



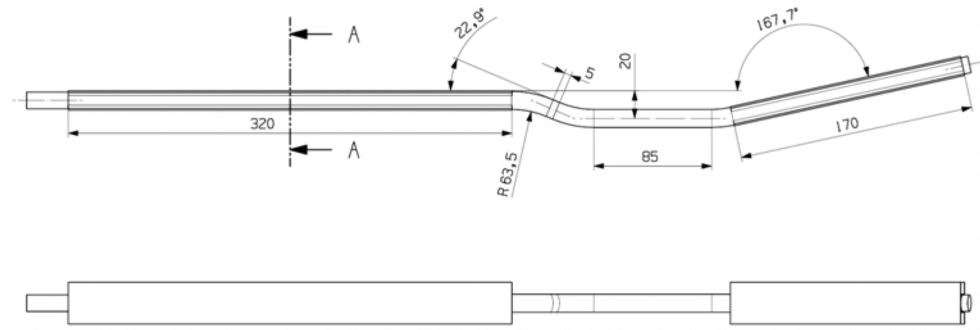
Cryocooler Plumbing Layout



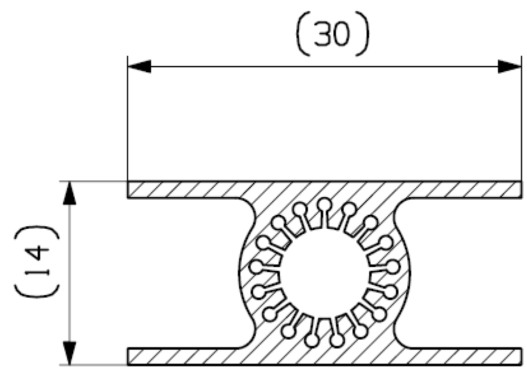
Cryocooler Zenith Radiator – Four Sub-Panel Layout



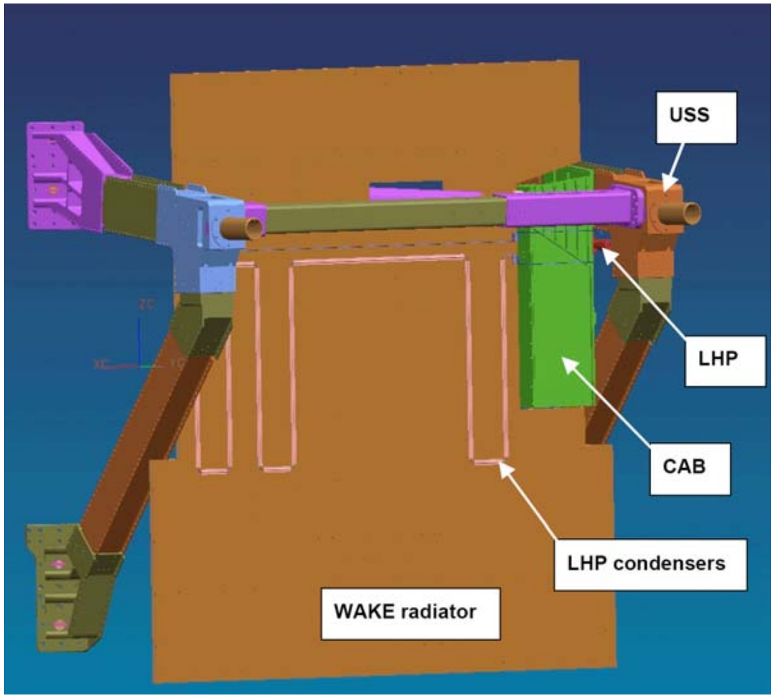
USS Heat Pipes on USS-02



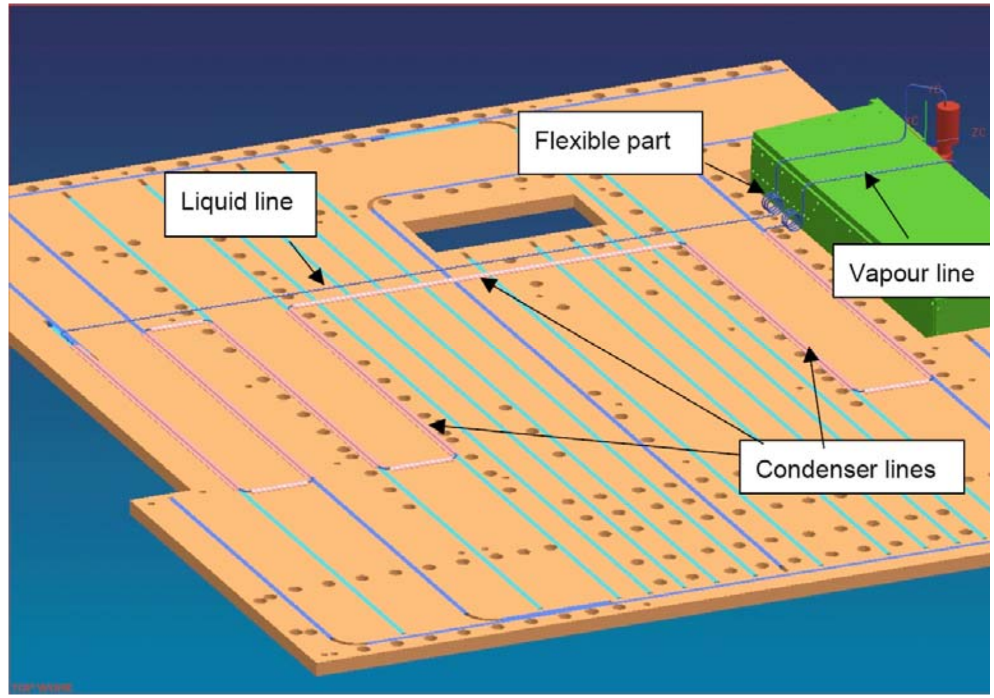
USS Heat Pipe Construction (mm)



USS Heat Pipe Cross section, (mm)



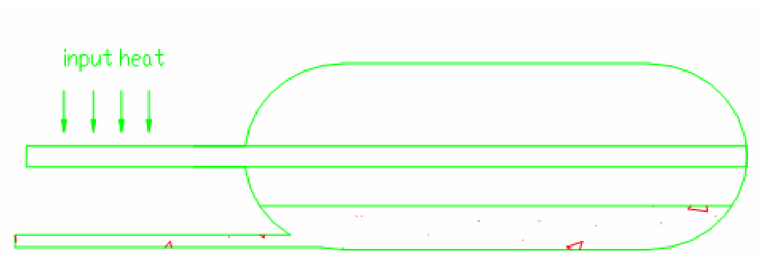
CAB Loop Heat Pipe



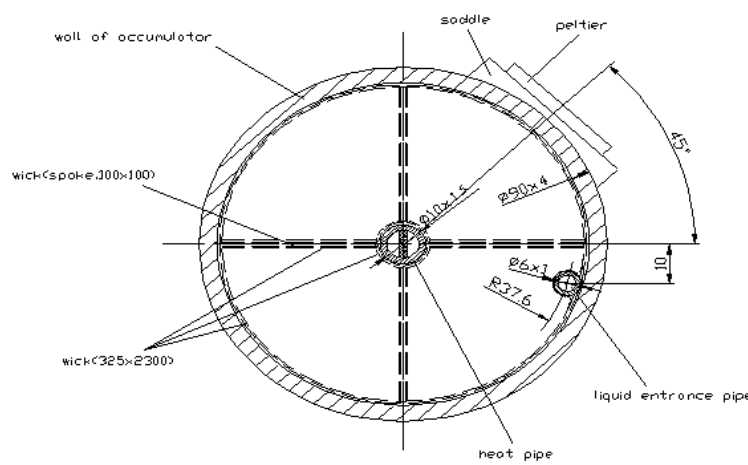
CAB Loop Heat Pipe Layout

TBS CAB Heat Pipe

CAB Heat Pipe



TTCS Accumulator Heat Pipe Cross Section



TTCS Accumulator Heat Pipe Cross Section